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Thesis: Renormalization of an arbitrary renormalizable model in a gauge symmetry violating regularization

Summary

The thesis concerns loop calculations in a nonstandard regularization defined by the replacement

$$\partial_\mu \mapsto \exp \left\{ \partial^2 / (2\Lambda^2) \right\} \partial_\mu$$

for all derivatives in the Lagrangian.

In Chapter 1 we explain our main motivations.

In Chapter 1 we develop practical methods for calculations in this regularization. We also introduce an appropriate minimal subtraction scheme ($\Lambda\text{-}\overline{MS}$) for an arbitrary renormalizable model. Because of violations of the gauge symmetry induced by regularization, we have to decide which vertices are minimally renormalized – by our choice these are all vertices without vector fields. In Section 2.4 we show that this choice determines 1PI effective action unambiguously provided that the “vertex” $A_\mu \partial^2 A^\mu$ as well as all vertices containing fields carrying nonzero ghost number are also minimally renormalized. There are four stages of calculation of 1PI Green functions at the \hbar order: (1) determination of violation of a Slavnov-Taylor identity for regularized one-loop diagrams, (2) minimal renormalization of *all* vertices, (3) determination of violation of the ST identity for minimally renormalized 1PI functions, (4) determination of additional counterterms for vertices with vector fields from the condition of restoration of the ST identity. This procedure is performed in Chapter 3, and the complete set of additional counterterms is determined at one-loop.

In Chapter 4 we show that $\Lambda\text{-}\overline{MS}$ is equivalent with \overline{MS} scheme of dimensional regularization with “naive” γ^5 (DimReg- \overline{MS}). To this end we check that the one-loop 1PI functions in both schemes are related through “finite renormalization” of fields and couplings. So obtained relations between

renormalized parameters allow for the conversion of well-known two-loop β functions in DimReg- \overline{MS} into their counterparts in $\Lambda\text{-}\overline{MS}$ – this is done in Chapter 5.

As an additional consistency check we calculate – in Chapter 6 – divergent parts of two-loop vacuum diagrams in $\Lambda\text{-}\overline{MS}$. We show that overlapping divergences are removed correctly in this scheme. Moreover, this calculation allows for a *direct* derivation of two-loop β functions for scalar couplings in $\Lambda\text{-}\overline{MS}$ – the result is consistent with the one obtained in Chapter 5.

In Chapter 7 we discuss possible applications of our results in the context of the hierarchy problem.

Appendices A, I, H and C.2 contain calculations that are integral parts of the thesis. Remaining appendices contain a supplementary material.